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Toxic Heavy Metals: Lead and Mercury Overview

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Toxic heavy metals like lead and mercury are dense metals known for their significant toxicity and environmental impact. Found naturally in the earth, they become concentrated due to human activities such as mining, industrial processes, and vehicle emissions, contaminating air, water, and soil. Lead exposure, primarily from industrial sources, old paints, batteries, and plumbing, disrupts plant growth and causes severe health issues in humans, including neurological and kidney disorders. Mercury, released from mining and industrial waste, accumulates in aquatic systems, leading to human exposure through contaminated seafood and causing neurological and renal problems. These metals enter organisms through inhalation, ingestion, and contact, causing acute and chronic health effects, including cancers and nervous system damage. Phytoremediation is a promising technology that uses plants to clean contaminated environments, reducing heavy metal concentrations through stabilization, degradation, and accumulation processes.

Introduction

A toxic heavy metal is any relatively dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. The term has application to cadmium, mercury and lead, all of which appear in the World Health Organization's list of 10 chemicals of major public concern. Other examples include manganese, chromium, cobalt, nickel, copper, zinc, silver, antimony and thallium.

Heavy metals are found naturally in the earth. They become concentrated as a result of human caused activities and can enter plant and animal (including human) tissues via inhalation, diet, and manual handling. Then, they can bind to and interfere with the functioning of vital cellular components. The toxic effects of arsenic, mercury, and lead were known to the ancients, but methodical studies of the toxicity of some heavy metals appear to date from only 1868.

Lead

Lead is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. Lead is a bright silvery metal, slightly bluish in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds, depending on the given conditions. The sources of lead exposure include mainly industrial processes, food and smoking, drinking water and domestic sources. The sources of lead were gasoline and house paint, which has been extended to lead bullets, plumbing pipes, pewter pitchers, storage batteries, toys and faucets. Lead is an extremely toxic heavy metal that disturbs various plant physiological processes and unlike other metals, such as zinc, copper and manganese, it does not play any biological functions. A plant with high lead concentration fastens the production of reactive oxygen species

(ROS), causing lipid membrane damage that ultimately leads to damage of chlorophyll and photosynthetic processes and suppresses the overall growth of the plant. Even at low concentrations, lead treatment was found to cause huge instability in ion uptake by plants, which in turn leads to significant metabolic changes in photosynthetic capacity and ultimately in a strong inhibition of plant growth.

Mercury

The metallic mercury is a naturally occurring metal which is a shiny silver-white, odorless liquid and becomes colorless and odorless gas when heated. Mercury is very toxic and exceedingly bio-accumulative. Its presence adversely affects the marine environment. Major sources of mercury pollution include anthropogenic activities such as agriculture, municipal wastewater discharges, mining, incineration, and discharges of industrial wastewater. Mercury exists mainly in three forms: metallic elements, inorganic salts and organic compounds, each of which possesses different toxicity and bioavailability. These forms of mercury are present widely in water resources such as lakes, rivers and oceans where they are taken up by the microorganisms and get transformed into methyl mercury within the microorganism, eventually undergoing biomagnification causing significant disturbance to aquatic lives. Consumption of this contaminated aquatic animal is the major route of human exposure to methyl mercury. Mercury is extensively used in thermometers, barometers, pyrometers, hydrometers, mercury arc lamps, fluorescent lamps and as a catalyst. It is also being used in pulp and paper industries, as a component of batteries and in dental preparations such as amalgams.

Sources

Heavy metals are found naturally in the earth, and become concentrated as a result of human activities or in some cases geochemical processes, such as accumulation in peat soils that are then released when drained for agriculture. Common sources are mining and industrial wastes, vehicle emissions motor oil, fuels used by ships and heavy machineries, construction works, fertilizers, pesticides, paints, dyes and pigments, renovation, illegal depositing of construction and demolition waste, open top roll-off dumpster, welding, brazing and soldering, glass working, concrete works, roadworks, use of recycled materials, burning of joss paper, open burning of waste in rural area, contaminated ventilation system, food contaminated by the environment or by the packaging, armaments, lead-acid batteries, electronic waste recycling yard, treated woods, aging water supply infrastructure and microplastics floating in the world's oceans.

Entry routes

Heavy metals enter plant, animal and human tissues via air inhalation, diet, and manual handling. Motor vehicle emissions are a major source of airborne contaminants including arsenic, cadmium, cobalt, nickel, lead, antimony, vanadium, zinc, platinum, palladium and rhodium. Water sources (groundwater, lakes, streams and rivers) can be polluted by heavy metals leaching from industrial and consumer waste, acid rain can exacerbate this process by releasing heavy metals trapped in soils. Transport through soil can be facilitated by the presence of preferential flow paths (macropores) and dissolved organic compounds. Plants are exposed to heavy metals through the uptake of water, animals eat these plants, ingestion of plant- and animal-based foods are the largest sources of heavy metals in humans.

Detrimental effects

Heavy metals "can bind to vital cellular components, such as structural proteins, enzymes, and nucleic acids, and interfere with their functioning". Long-term exposure to toxic heavy metals can have carcinogenic, central and peripheral nervous system, and circulatory effects.

Table 1. Detrimental effects of toxic elements

Element	Acute exposure (usually a day or less)	Chronic exposure (often months or years)
Mercury	Diarrhea Fever Vomiting	Stomatitis (inflammation of gums and mouth) Nausea Nephrotic syndrome (nonspecific kidney disorder) Neurasthenia (neurotic disorder) Parageusia (metallic taste) Pink Disease (pain and pink discoloration of hands and feet) Tremor
Lead	Encephalopathy (brain dysfunction) Nausea Vomiting	Anemia Encephalopathy Foot drop/wrist drop (palsy) Nephropathy (kidney disease)

Phytoremediation Technology

phytoremediation is defined as an emerging technology using selected plants to clean up the contaminated environment from hazardous contaminant to improve the environment quality.

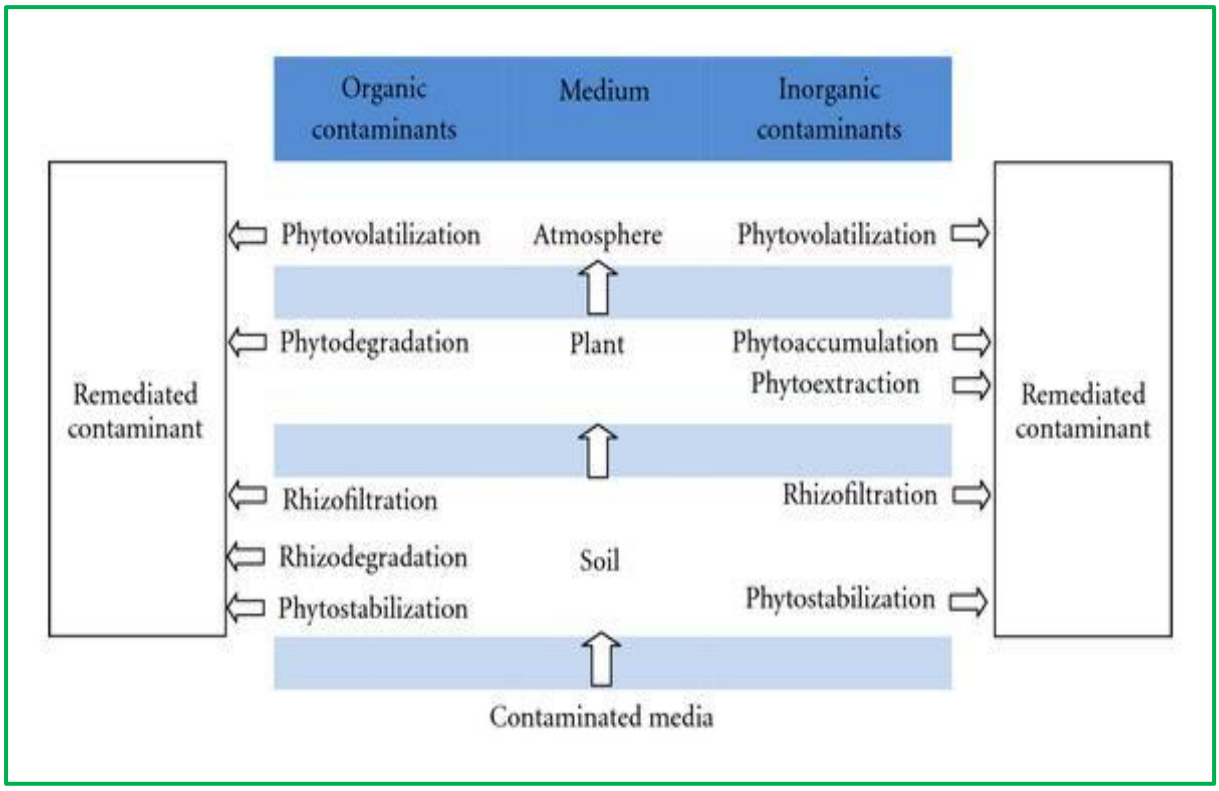

Fig. 1 The uptake mechanisms of both organics and inorganics contaminants through phytoremediation technology

For organics, it involves phytostabilization, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatilization. These mechanisms related to organic contaminant property are not able to be absorbed into the plant tissue. For inorganics, mechanisms which can be involved are phytostabilization, rhizofiltration, phytoaccumulation and phytovolatilization.

Conclusion

Toxic heavy metals such as lead and mercury pose significant environmental and health risks due to their persistence, bioaccumulation, and ability to disrupt biological systems. Human activities have exacerbated the concentration and distribution of these metals, leading to widespread contamination of soil, water, and air. Exposure through various routes—including inhalation, ingestion, and direct contact—can cause severe acute and chronic health effects, affecting the nervous system, kidneys, and overall metabolic functions in humans, as well as disrupting plant growth and ecological balance. Effective management and remediation strategies, such as phytoremediation, are crucial for mitigating their impact, offering sustainable solutions to reduce heavy metal contamination and protect environmental and public health.